# TECHNICAL EFFICIENCY OF SHRIMP FARMING IN COASTAL MAHARASHTRA : A PRODUCTION FUNCTION APPROACH

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## ABSTRACT

**Among the different shrimp species cultured in India Tiger shrimp, *Peneaus monodon* is the most popular and commands considerable demand all over India including Maharashtra. In India, about 1.2 million hectares of potential area is suitable for shrimp farming. It has estimated that about 1.45 lakh tonnes of shrimp were produced during the year 2006. Shrimp farming has helped to increase the employment due to increase in production, transport, processing, marketing and export trade. However, the industry suffered various shocks including white spot disease, price fluctuation at international level and threat of antidumping by USA which resulted in increased risk in production and marketing, all these issues have direct bearing on the profitability and economics of shrimp farming operations. The present study on the technical efficiency of shrimp farming in the costal Maharashtra comprised of analysing the status of the shrimp farming in the costal districts of Maharashtra, *viz.,* Thane, Raigad, Ratnagiri and Sindhudurg.The data on the shrimp farming was collected form a total sample size of 110 farmers using a pretested questionnaire. The technical efficiency was estimated using Cobb Douglas production function. The results revealed that the water spread area, stocking density per hectare, fertilizer used and stocking density were the most important factors for determining the production of shrimp in all over Maharashtra. The cost of seed, quantity of feed and culture period were the most pertinent factors for determining the production of shrimp in Thane district. The culture period and quantity of feed were the most important factors for determining the production of shrimp in Raigad district. Stocking density, medicines cost and feed required were the most important factors for determining the production of shrimp in Ratnagiri and Sindhudurg districts. The study suggested the need for the concerted efforts in developing a disease management plan and evolving a viable marketing strategy for augmenting the production and higher unit value realisation for the shrimp production .**

**Key words: Technical efficiency, shrimp farming, coastal Maharashtra.**

## INTRODUCTION

Fisheries play an instrumental role in the socio-economic development of the country, as it is a valuable source of livelihood for a huge section of economically backward population. Among the different fisheries enterprises, aquaculture is the fastest growing food sector in the world. Over the last few decades, aquaculture has taken off in India from a mere subsistence to a profitable commercial enterprise. In India, there exists about 1.2 million hectare of potential area suitable for shrimp farming of which an area of about 1.57 lakh hectare is under farming. It has been estimated that about 1.45 lakh tonne of shrimp was produced during 2010-11. The average productivity has been estimated at 660 kg / hectare per year. The cultured shrimps contribute about 50 per cent of the total shrimp exports from India. Shrimp farming provides direct employment to about 0.3 million people and ancillary units provide employment to 0.6 – 0.7 million people (FAO, 2009).

Maharashtra, the third largest state in the country in terms of area and population with a coastline of 720 km and continental shelf area of over 0.11 million sq. km, offers rich resources for marine fish production. Maharashtra has about 80000 hectares of brackish water area suitable for shrimp farming. Presently, approximately 12,445 ha land is suitable for brackish water culture in Maharashtra, among which 1,056 hectares area has been developed during past two decades or so. Development of aquaculture has been one of the most outstanding features of fisheries sector in the country including Maharashtra state. It is one of the major reasons for doubling the shrimp production not only from Maharashtra state, but also of the whole country. The costal districts of Maharashtra, *viz,* Greater Mumbai, Thane, Raigad, Ratnagiri and Sindhudurg are having suitable areas for shrimp culture (DoF, 2010).

Due to over exploitation of marine fish, lower catch per unit effort and low price realization compound the problems of the primary stakeholders, *viz.,* the fishermen. There is a scarcity of fish to meet the ever-growing demand in the market. Shrimp is the highly demanded species in the international market and due to this factor it fetches a good price and foreign exchange. Thus, shrimp farming is the best alternative to increase the production (Andrew, 1999). In addition, utilization of vast areas which are not suitable for agriculture can be a way to augment fish production in the state and country. Shrimp farming can be done in the controlled conditions but it has some technical and economical problems. Shrimp farmers are also facing a lot of threats like white spot disease and other viral diseases, low rate for produce, high cost of production, natural disasters, flood problems, poaching of shrimps and other accessories, no quality seed, high rate of seed *etc.* (Das, 2005). Huge capital investment is required to be made in brackish water shrimp farm for construction of bunds, sluice gates and equipment during initial years (Raju,

2002). However, the industry suffered various shocks including white spot disease, price fluctuation at international level and threat of antidumping by USA which resulted in increased risk in production and marketing. All these issues have direct bearing on the profitability and economics of shrimp farming operations (Shang *et al*., 1998). As such, development of shrimp farming industry is at very slow pace in Maharashtra as compared to other states of India (Reddy and Raghunadha, 2004). In view of these, the present study on technical efficiency of shrimp farming in coastal Maharashtra was undertaken with following objectives.

The overall objective of the study is to analyze the status and prospects of shrimp farming in the different coastal districts of Maharashtra, *viz.,* Thane, Raigad, Ratnagiri and Sindhudurg.

However, the specific objectives were:

1. To analyze the technical efficiency of the shrimp farmers,
2. To suggest policy guidelines for augmenting shrimp production in the state.

## DATA AND METHODOLOGY

The study was conducted in the coastal districts of Maharashtra ( Figure 1). Thane, Raigad, Ratnagiri and Sindhudurg districts were purposively selected for the present study. These four districts play a very important role in brackish water fisheries in Maharashtra as they are situated in the coast of Arabian Sea and have a plenty of brackish water resources. The farmers were highly encouraged to undertake adoption of improved practices in shrimp farming to increase the yield of shrimp. Based on the probability proportional sampling method and taking into consideration the area under shrimp farming and shrimp production, out of the total sample of 110 respondents, 44 were allotted to Thane district, while 33,22 and 11 selected from Raigad, Sindhudurg and Ratnagiri district respectively.

The sampling design of selected respondents list is furnished in Figure 2. The study is based on primary and secondary data. Primary data were collected from the sample respondents in the selected four study areas, by personal interview method. The personal interview was conducted with the help of a pre-structured, comprehensive questionnaire (interview schedule) and was pretested with a reconnaissance study.

**Figure 1: Map of Maharashtra**

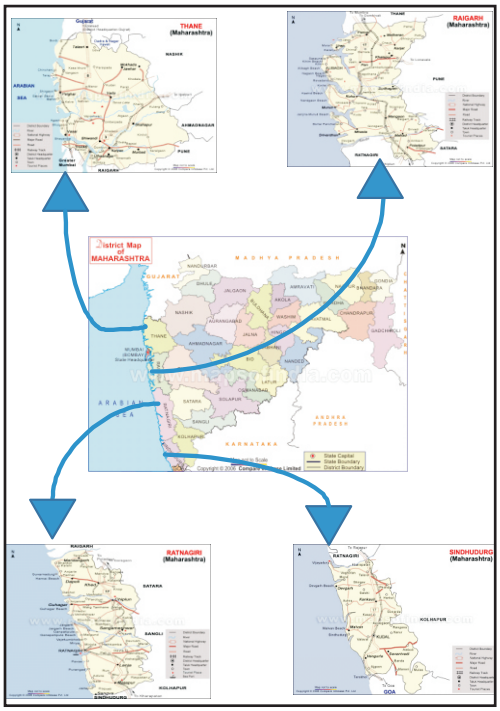
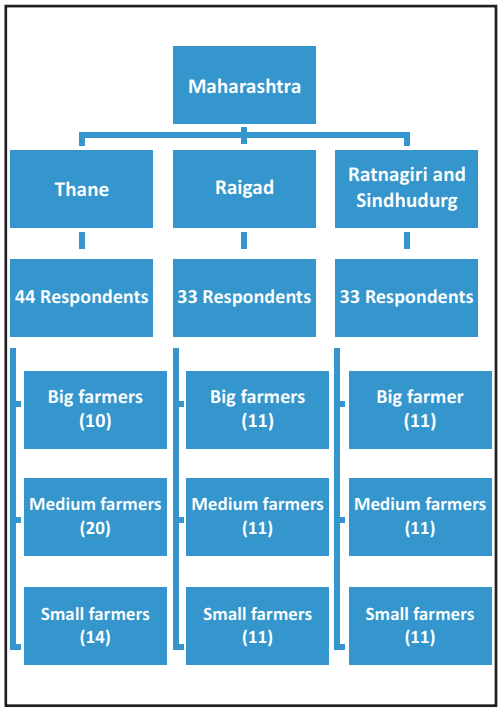



**Figure 2 Sampling design of respondents**




The Production function - Cobb-Douglas production Function Analysis was employed to evaluate the factors influencing the shrimp production. Production function is a mathematical expression of the relationship between the quantity produced and factors affecting the quantity produced. For example, the quantity of shrimp produced is determined by the different factors like the area of the farm, quantity of seed, experience of farming, culture period, stocking density, quantity of feed, cost of fertilizers and labour man days *etc.* The production function is expressed as:

Y = f (A, S, E, P, D, F, Ft, L, M)
Where,
Y = Yield of shrimp in tonnes per hectare
A = Area of the farm in hectare
S = Quantity of seed used in numbers
E = Experience of farming in years
P = Culture period in days
D = Stocking Density in number
F = Quantity of feed applied in tonnes
Ft = Cost of fertilizers in lakh rupees
L = Labour in mandays
M = Medicine cost in rupees.

Based on the scatter diagram, the Cobb-Douglas (CD) production function was found to be the best fit. The dependent variable was Y = Yield in kilogram , while the independent variables were A= water spread area of farm in hectare, S= quantity of seed used in numbers, E= experience of farming in years, P= culture period in days, D=

stocking density per ha. F= feed applied in tonnes, M= cost of medicine, Ft= fertilizers used, L= Labour required in mandays.

**The functional form of the model is as follows:**

$Y = a A^b S^c E^d P^e D^f F^g M^h Ft^i L^j e^\mu$

Where, a = intercept

$e^\mu$ = error term

Y= Yield (dependant variable)

X = Inputs (independent variable)

b, c, d, e, f, g, h, i, j are the elasticity coefficient

Here the linear form of the CD production function is:

$\ln Y = \beta + b \ln A + c \ln S + d \ln E + e \ln P + f \ln D + g \ln F + h \ln M + i \ln Ft + j \ln L$

**Table 1. Shrimp production in the coastal districts of Maharashtra (tonnes/ ha / crop)**

| Sl. No. | Productivity | Thane | Raigad | Ratnagiri | Sindhudurg | Total |
|---|---|---|---|---|---|---|
| 1. | 0-1 | 13 (29.55) | 14(42.42) | 0(0.00) | 6(27.27) | 33(30.00) |
| 2. | 1-1.5 | 23 (52.27) | 8(24.24) | 5(45.45) | 13(59.09) | 49(44.55) |
| 3. | 1.5-2.0 | 7 (15.91) | 8(24.24) | 3(27.27) | 2(9.09) | 20(18.18) |
| 4. | 2.0-2.5 | 1 (2.27) | 2(6.06) | 1(9.09) | 1(4.55) | 5(4.55) |
| 5. | More than 2.5 | 0 (0.00) | 1(3.03) | 2(18.18) | 0 (0.00) | 3(2.73) |
| 6. | Total | 44 (40.00) | 33(30.00) | 11(10.00) | 22(20.00) | 110(100.00) |

(Figures in parentheses indicate percentage to total)

## RESULTS AND DISCUSSIONS

The results and discussions of the shrimp farming in the different coastal districts is provided under the following sections:

### A. Shrimp production in different coastal districts

The results of shrimp production in the different coastal districts of Maharashtra are given in Table 1. The productivity distribution of the shrimp yield across the farms in the different coastal districts are indicated in Table 1, and categorized into 5 groups, viz. 0-1, 1-1.5, 1.5-2, 2-2.5, more than 2.5.

During the study, productivity of shrimp yield of the 110 samples was studied. It has been indicated that 44.55 per cent of the respondents were belonging from the category having productivity of 1 to 1.5 tonnes/ha followed by 30 per cent of the respondents having the productivity range between 0 to 1 tonnes/ha. About 25 per cent of the respondents were having the productivity 1.5 tonnes/ha. and more.

In Thane district, majority of the sample respondents (52.3 per cent) were having productivity between 1-1.5 tonnes/ha followed by 29.55 per cent respondents having productivity of less than 1 tone/ha. Only about 18 per cent of the respondents had productivity in

between 1.5-2.5 tonnes/ha in Thane district. Unlike Thane, in the Raigad district, 42.42 per cent of the sample respondents were having the productivity less than 1 tonne/ha, followed by farmers (8each) producing 1-1.5 tonnes/ha and 1.5-2.0 tonnes/ha. Only 6 per cent and 3 per cent of the sample respondents were belonging the category of 2.0 to 2.5 tonnes/ha and more than 2.5 tonnes/ha productivity respectively (Table 1).

In case with Ratnagiri district, none of the sample respondents were having the productivity less than 1 tonne/ha. About half of the respondents (45.45 per cent) had productivity in between 1-1.5 tonnes/ha while about $1/4^{th}$ ( 27.27 per cent) respondents reported the productivity in between 1.5-2.0 tonnes/ha. Only 9.09 per cent of the sample respondents were belonging to the group having the productivity 2.0 to 2.5 tonnes/ha and 18.18 per cent of the respondents had the productivity more than 2.5 tonnes/ha. In case of Sindhudurg district, majority of respondents (60 per cent ) were having productivity between 1-1.5 tonnes/ha followed by about $1/4^{th}$ of respondents having the productivity of less than 1 tonne/ha. Only two and one respondents were having the productivity in between 1.5-2.0 tonnes/ha and 2.0 to 2.5 tonnes/ha respectively and none of the respondents had the productivity of more than 2.5 tonnes/ha in Sindhudurg district (Table 1). The shrimp productivity yields of all the coastal districts of Maharashtra indicated that 1-1.5 tonnes was the average productivity for about 45 per cent of the sample respondents.

**B. Technical Efficiency of Shrimp farming**

Districtwise technical efficiency of shrimp farming is analysed and presented below:

**Thane District**

The Cobb-Douglas production function analysis of Thane district was,

$$Y=- 6.299\ A^{0.042}\ S^{0.457}\ E^{0-01}\ P^{1.157}\ D^{0.107}\ F^{0.243}\ M^{0.085}\ F^{0.035}\ L^{0.083}$$

Where
a= -6.299 ,b= 0.042, c=0.457, d= 0.01, e= 1.167, f= 0.107, g= 0.243, h=0.085, i=0.035, j=0.083

The linear form of the equation is

$$\ln Y = \ln(-6.299) + 0.042 \ln A + 0.457 S^{***} + 0.01 \ln F + 1.167 \ln P^{***} +$$
(0.263) (0.078) (0.169) (0.068) (0.220)

$$0.107 \ln D + 0.243 \ln F^{**} + 0.085 \ln M + 0.035 \ln Ft + 0.083 \ln L$$
(0.209) (0.127) (0.149) (0.118) (0.159)

Since the function run, the Cobb- Douglas production function, the coefficient represents different elasticities, so according to production function:

c= elasticity for seed = 0.457
e= elasticity for culture period = 1.167
g= elasticity for feed = 0.243.

The production yield for Thane district indicated an R square ($R^2$) of 0.859 which explained that 85.9 per cent of the variation in the shrimp yield was

accounted by the selected independent variable. The F- value was found to be 97.573 at one per cent level of significance. Among the variables under study, elasticity of seed (C) was 0.457 which explained that for every ten per cent increase in the seed (S) the yield (Y) increased by 4.57 per cent from the mean level *ceteris paribus.* Elasticity of culture period (e) was 1.167. For every 10 per cent increase in culture period (P), the yield of cultured shrimp (Y) increased by 11.6 per cent from the mean level *ceteris paribus.* Elasticity of feed (g) was 0.243. For every 10 per cent increase in feed (g) the yield of cultured shrimp (Y) increased by 24.3 per cent from the mean level *ceteris paribus.* The result indicates that number of seed and cultured period were most important factors in determining the yield of shrimp in Thane district.

The economies of scale was found to be equal to 2.23, this explains the incidence of increasing returns to scale in the traditional shrimp farming systems of Thane. In other words, it implied that if all the inputs are increased specified in the function by ten per cent, the output will increase by 22 per cent.

**Raigad district**

The result of production function analysis of Raigad district has been detailed below.

The Cobb-Douglas production function for Raigad district was

$Y = -10.415\ A^{-0.009}\ S^{-0.077}\ E^{0.0192}\ P^{1.536}\ D^{0.633}\ F^{1.211}\ H^{-0.125}\ Ft^{0.227}\ L^{0.433}$

Where,

a= -10.415, b= -0.009, c=-0.007, d= 0.0192, e= 1.536, f= 1.211, g = -0.725, h= 0.227, i=0.433

$\ln Y = \ln(-10.415) - 0.009 \ln A - 0.77 \ln S + 0.019 \ln E + 1.536 \ln P^{***}$
(4.704) (0.776) ( 0.761) (0.260) (0.704)

$+ 0.683 \ln D + 1.211 \ln F^{**} - 0.725 \ln M + 0.227 \ln F + 0.433 \ln L$
(0.872) (0.642) (0.645) (0.454) (0.634)

e= elasticity for culture period = 1.536
g= elasticity for feed = 1.211

Note: These have got significance in the production function.

The yield of shrimp in Raigad district indicated the R square ($R^2$) of 0.79 which meant that 79 per cent of variation in the yield of shrimp was explained by the selected independent variables. F- values were found to be 17.657 and thus significant at one per cent level . Among the different independent variable under study, elasticity of culture period (e) was found to be1.536. For every 10 per cent increase in the culture period (P), the yield of shrimp cultured increased by 15.36 per cent from the mean level *ceteris paribus. The elasticity* of feed (F) was 1.211. For every 10 per cent increase in the feed (F), the yield of shrimp cultured increased by 12.11 per cent from the mean level *ceteris paribus*. The result indicated that culture period and feed were the most important factors in determining the yield of shrimp in Raigad district. The returns to scale for the shrimp farming in Raigad was found to be 3.24 which explained the increasing returns to scale in the traditional shrimp

farming systems of Raigad district. In other way, it indicated that if farmers increase all the inputs specified in the function by ten per cent, the output will increase by 32.4 per cent.

**Ratnagiri and Sindhudurg districts**

The results of production function analysis of Ratnagiri and Sindhudurg districts have been mentioned below. The Cobb-Douglas production function for the Ratnagiri and Sindhudurg districts was,

$Y= -3.586\ A^{0.178}\ S^{0.026}\ E^{-0.037}\ P^{0.0218}\ D^{0.419}\ F^{0.339}\ M^{0.386}\ F^{-0.170}\ L^{0.234}\ E^{-0.011}$

Where,

a= -3.586 b=0.178, c=0.026, d= -.037, e= 0.218, f= 0.419, g= 0.339,

h= 0.386, i=-0.170, j= 0.234

The linear form is as given below

$\ln Y = \ln(-3.586) + 0.178 \ln A + 0.026 \ln S - 0.037 \ln E + 0.218 \ln P$

(-3.014) (0.770) ( 0.272) (-0.416) (0.944)

$+0.419 \ln D^{**} + 0.339 \ln F^{**} + 0.386 \text{ Ln } M^{*} - 0.170 \ln Ft + 0.234 \ln L$

(1.964) (1.763) (-0.925) (1.479) (2.013)

f= elasticity for stocking density = 0.056
g= elasticity for feed = 0.339
h= elasticity for medicine =0.386

The yield of shrimp in Ratnagiri and Sindhudurg districts indicated the R square ($R^2$) of 0.083and it means that 83 per cent of variation in the yield of shrimp was explained by the selected independent variables. F- values were found to be 48.590 and showed one per cent of significance. Among the different independent variables under study, elasticity of stocking density (f) was 0.056. For every 10 per cent increase in stocking density (D), the yield of shrimp cultured increased by 0.56 per cent from the mean level *ceteris paribus.* Elasticity of medicine (h) was 0.386. For every 10 per cent increase in the medicine (M), the yield of shrimp cultured increased by 3.8 per cent from the mean level *ceteris paribus*. Elasticity of feed (g) was 0.339. For every 10 per cent increase in the feed (F), the yield of shrimp (Y) cultured increased by 3.39 per cent from the mean level *ceteris paribus.*

The result indicated that stocking density, feed and medicine were the most important factors in determining the yield of shrimp. The returns to scale of the shrimp production was found to be 1.4, this explains the incidence of diminishing returns to scale in the traditional shrimp farming systems of Sindhudurg and Ratnagiri districts. In other words, it suggested that if all the inputs are increased specified in the function by ten per cent, the output will get increased by 14 per cent.

**Entire Maharashtra**

The results of the analysis of Maharashtra state have been illustrated below:

The Cobb – Douglas production function for the Maharashtra state was $Y= -0.088\ A^{0.138}\ S^{-0.026}\ E^{-0.007}\ P^{0.019}\ D^{0.0194}\ F^{0.660}\ M^{-0.020}\ Ft^{0.193}\ L^{-0.001}$

Where,

a= -0.088 , b= 0.138, c=-0.026, d=-0.0007, e=0.019, f=0.0019, g=0.660, h=0.020, i=0.193, j=-0.001

The linear form of the production function is

$$\ln Y = \ln(-0.0887) + 0.138 \ln A^{***} - 0.026 \ln S - 0.007 \ln E + 0.019 \ln P$$
(0.713) (0.087) (0.087) (0.051) (0.113)

$$+0.019 \ln D^{**} + 0.660 \ln F^{*} - 0.020 \ln M + 0.193 \ln Ft^{*} - 0.001 \ln L$$
(0.112) (0.091) (0.041) (0.082) (0.001)

Note:
1. Figures in these parentheses represent standard error.
2. $^{*}$ $^{**}$ and $^{***}$ denotes to one, five and ten per cent of level of significance.

Since the function run, in the Cobb –Douglas production function, the coefficient represents the different elasticities. So according to the production function:

b= elasticity of water spread area = 0.188
f= elasticity of stocking density = 0.019
g= elasticity of feed used = 0.660
I= elasticity of fertilizer used = 0.193

The production for Maharashtra state indicated the R square ($R^2$) of 0.814. This means that 81.4 per cent of the variation in yield is explained by the selected independent variables. F- Value was found to be 130.1 and was significant at one per cent level. Among the different variables under study, elasticity of water spread area (b) was 0.138 which indicated that for every 10 per cent increase in the water spread area (A), the yield of shrimp culture (Y), increased by 13.8 per cent from the mean level at *ceteris paribus*. The elasticity of stocking density per hectare (F) was 0.019 that for every 10 per cent increase in the stocking density per hectare (D), the yield of shrimp culture (Y) increased by 1.9 per cent from the mean level at *ceteris paribus.* The elasticity of feed used (g) was 0.660. For every 10 per cent increase in feed used (f), the yield of culture shrimp (Y) increased by 6 per cent. Elasticity of fertilizer used (i) was 0.193. So for ever y 10 per cent increase in the fertilizer used (Ft), the yield in cultured shrimp (Y) increased by 19 per cent.

`The result indicated that stocking density, feed, electricity and fertilizer were the most important factors in determining yield (Y) of the shrimp. The results indicated that yield can be increased by the application of more feed and fertilisers.

The economies of the scale for the technical efficiency of shrimp farming in Maharashtra exhibited as 1.15 and it explains the incidence of increasing returns to scale in the traditional shrimp farming systems of Maharashtra. In other

words, it indicated that if shrimp farmers increase all the inputs specified in the function by ten per cent, the output will increase by 11.5 per cent.

## CONCLUSIONS

The results of the study on the technical efficiency of shrimp farming using Cobb Douglas production function analysis in Coastal Maharashtra revealed the following results

The water spread area, stocking density per hectare, fertilizer used and stocking density were the most important factors for determining the production of shrimp in Maharashtra. The returns to scale indicated that on increasing the inputs specified in the function by ten per cent, the output will increase by 11.5 per cent. The cost of seed, quantity of feed, and culture period were the most pertinent factors for determining the production of shrimp in Thane district.

The culture period and quantity of feed were the most important factors for determining the production of shrimp in Raigad district. In Raigad, if all the inputs specified in the function increased by ten per cent, the output will increase by 32.4 per cent.

Stocking density, medicines cost and feed required were the most important factors for determining the production of shrimp in Ratnagiri and Sindhudurg districts. In these areas, if all the inputs specified in the function increased by ten per cent, the output will increase by 14 per cent.

## Recommendation and Policy Suggestions

The area analysis indicated that a minimal area is under shrimp farming in Maharashtra. In order to augment shrimp production in the state, there is a need to have horizontal integration by ploughing in more areas as only less than 10 per cent of the suitable brackish water area is exploited. The hatcheries in Maharashtra are non - operational which lead to the high cost of seed due to cost of transportation and disease occurrence stock. Thus, there is an immediate need for governmental interventions .The feed cost accounts for 40 to 45 per cent of the total cost as they are imported from South East Asian countries. There is also a need to develop low cost feed harnessing the indigenous technical knowledge. Mostly farmers are facing the problems of viral diseases like WSSV and therefore farmers should take initiative to prevent spread of the destructive viral problems. Government agencies like MPEDA, BFDA *etc.* should provide consultancy for the farmers about site selection and pond construction to avoid losses due to flood and for better management practices. As there are huge economical loss due to diseases and other technical problems, farmers should be facilitated with crop insurance scheme.

## REFERENCES

**Andrew, P.,** 1999. Economics of Brackish water Shrimp Culture,. Daya Publishing House, Delhi. pp.1-134.

**Das, B. K.,** 2005. Sharing experiences on Shrimp Health Management in Farmers' Pond, *Aqua International,* pp. 29-30.

**Department of Fisheries,** 2010. Brackish Water Aquaculture Resources of Maharashtra, Government. of Maharashtra, Mumbai

**FAO,** 2009. htpp:www.fao./fishery/legalfremwork/india.

**Raju, M. S.,** 2002. Semi intensive shrimp farming system of Kerala, India: A producton function analysis. *Journal of the Indian Fisheries Association*, 29, pp.23-36.

**Reddy, Raghunadha G.,** 2004. Economic analysis of shrimp aquaculture in West Godavari District of Andhra Pradesh, India. *Journal of Fisheries Economics nd Development,* Vol V, No.2, pp.1-24.

**Shang, Y. C., Leung P. and Ling B. H.,** 1998. Comparative economics of shrimp farming in Asia. *Aquaculture*, 164, pp.183-200.